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THE STUDY ON THE INTERFACE REACTION CHARACTERISTICS OF DIFFERENT BINARY SLAG, CaO – MgO, Al_2O_3 – CaO, Al_2O_3 – MgO, SiO_2 – CaO, SiO_2 - MgO

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In this paper, thermodynamic calculation and different binary slag interface reaction experiments are used to study the reaction characteristics of different binary slag. The differences in melting process, wetting and reaction behavior were studied. The wetting angle of acidic slag is higher than that the corresponding basic slag. The variation of wetting angle between different binary slag is relatively small. The variation range is only 18 °C. In the melting and reaction process of different binary slag interfaces, the permeation and reaction of the CaO - MgO and CaO - SiO_2 interfaces are relatively sufficient. However, there is no obvious chemical reaction between CaO - Al_2O_3 and Al_2O_3 - MgO, and the composition and interface separation among each component are more obvious.

Key words: slag, CaO / MgO / Al_2O_3 / SiO_2, melting wetting, viscosity, interface reaction

INTRODUCTION

In addition to metal melt, slag is another important product of the process of smelting [1]. The characteristics of slag interface in metallurgical process involved a wide range of direction and field. In order to make the slag suitable for viscosity, activity, conductivity and other physical properties, the slag needed to have a higher degree of undercooling [2]. In the molten condition, a heterogeneous system of multiphase composites is formed among metal, slag, and refractory materials. And the inclusion adsorptions, refractories erosion always occurred at the interfaces [3-5]. The diffusion of elements, reaction behavior between slag, heat transfer between substances, furnace lining life of metallurgical reactor was closely related to the viscosity of the slag [6]. Therefore, in the most smelting processes, small slag viscosity is needed to increase the fluidity, which reduces the resistance in the mass transfer process.

Studying the interface properties such as melting, wetting, and infiltration of the slag interface, it is necessary to reveal the materialized features and the essence of the phenomenon [7-9]. At present, the study is limited to the process of corrosion and adsorption between slag and refractory or refractory and molten steel. There is a relative lack of research on the interface characteristics of slag itself.

In this paper, the melting, wetting, and reaction behaviors of different binary slag are studied under different influencing factors. The basic properties of slag are explored. There are also discussed the process and trend of interfacial behaviors such as dissolution, reaction and diffusion.

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EXPERIMENTAL

Raw materials and sample preparation

In this experiment, the raw materials were configured by Analytical Reagent. During the experiment, all experimental materials were evenly mixed using the pestle. The reactive matrix pressing parameters were shown in Table 1.

Table 1 **The reactive matrix pressing parameters**

Diameter / cm	Height / cm	Pressing force / Mpa
3	1,5	25
2,5	0,3	10
1	0,6	10
0,2	0,5	5

Experimental methods

Wetting refers to the process of forming a stable liquid-solid interface between liquid and solid surface, which replaces the gas on the solid surface with liquid [10]. In the experimental process, the component is used as a reactive matrix, and the slag to be studied is an experimental body for the experiment. Under the premise of ensuring that the lower substrate does not melt, and the molten slag can be completely wetted or reacted with the substrate. After the reaction, the sample was adopted cold cool mosaic method and cutting sectioned. The scanning electron microscope and other equipment were utilized to detect and analyze the interface. The melting process and wetting angle of the slag under different experimental conditions was achieved.

RESULTS AND DISCUSSION

Interface reaction temperatures and wetting angle

In order to explore the interfacial melting and reaction behavior between different binary slag, through testing device tests the change of melting characteristics of binary slag with different compositions. The corresponding results are shown in Table 2. The wetting angle in the binary slag melting process is shown in Table 3.

It can be seen from Table 2 that in the interfacial melting and reaction of different binary slag: as for CaO - MgO binary slag, during the reaction, the temperature of generating $Ca{\cdot}Mg(CO_3)_2$ is high. It leads to the initial and complete temperature of the interfacial reaction of the slags highly. The reaction temperature range was 48 °C. Al_2O_3 - MgO slag because high initial temperature of the interfacial reaction, Al and Magnesium element in the Al_2O_3 - MgO slag are not easy to react with other components.

From the phase diagram of the Al_2O_3 - MgO binary slag, it is found that when the interfacial reaction occurs in the binary slag, it is relatively easy to generate $MgO{\cdot}Al_2O_3$, which has a higher melting point. Therefore results in a relatively high reaction temperature and a change in the reaction characteristics.

For the interfacial reaction process of Al_2O_3 - CaO slag, the presence of more CaO at the interface and a large amount of Al in the slag sample will cause the slag to become too viscous. Through Al_2O_3 - CaO binary phase diagram can be obtained, when $12CaO{\cdot}7Al_2O_3$ was formed at the interface, the temperature of phase formation increased. The reaction temperature of slag system was 1 413 °C and the complete reaction temperature was 1 467 °C, resulting in a maximum reaction range of 54 °C.

As for the slag system containing SiO_2 (such as SiO_2 - CaO,SiO_2 - MgO), because the Si element at the interface between reactant and reactive matrix are relatively high.

So the higher Si content can promote the formation of a lower melting point silicate phase with other components. It can accelerate the melting speed, so its melting temperature is relatively low.

Table 2 **Slag interface reaction temperature / °C**

Slag sample	Interface reaction initial temperature	Interface complete reaction temperature	Reaction temperature range
CaO - MgO	1 449	1 497	48
Al_2O_3 - CaO	1 413	1 467	54
Al_2O_3 - MgO	1 479	1 497	18
SiO_2 - CaO	1 424	1 462	38
SiO_2 - MgO	1 396	1 425	29

Therefore, from Table 3, it can be seen that the wetting angle become 41°. During the Al_2O_3 - MgO slag sample reaction process, the initial formation temperature of $MgO{\cdot}Al_2O_3$ and Al_2MgO_4 are higher. When they are completely melted, with the increasing rate of Mg / Al, the content of Mg can also inhibit the activity of Al. Compared with Al_2O_3 - CaO slag, reaction interval between Al_2O_3 - MgO slag becomes shorter, which improves the wettability between Al_2O_3 - MgO slag. The wetting angle becomes 31°. $MgSiO_3$ and Mg_2SiO_4 form at the SiO_2 - MgO reaction interface. Due to the structure of them are mostly columnar or crystal particle, the bonding force is weaker. It results in a poor wetting of the slag with a wetting angle of 45°. As for the slag system containing SiO_2, the Si element at the interface between reactant and reactive matrix are relatively high. It is easier to generate $2CaSiO_3$ at a low melting point, which can accelerate the melting speed. Thus its melting temperature is lower and the wetting angle is 36 °. There is mainly $CaMg(CO_3)_2$ at the CaO - MgO interface, which can reduce the viscosity of slag when it is completely melted. At the same time $CaMg(CO_3)_2$ improves the wettability of molten slag and the wetting angle is 27°. It can be seen from Table 3 that the change of the wetting angle among 5 different binary slag is a little small.

Study on the interface reaction characteristics of different binary slag

From the phase diagram of the CaO - MgO binary slag, it can be seen that when CaO and MgO react, there is $CaMg(CO_3)_2$ at the interface. Figure 1 shows that the electron microscope surface scanning at the interfacial reaction between CaO - MgO slag, it can be seen that the structure and components of $CaMg(CO_3)_2$ are relatively uniform and dense. Compared with other components, the MgO at the interface clearly penetrates the reactive matrix into the slag and the CaO permeates into the reactive matrix from the slag. Therefore the reaction and penetration at the interface reaction are pretty well.

The electron microscope surface scanning at the interfacial reaction between Al_2O_3 - CaO slag is shown in Figure 2 It is discovered from the Al_2O_3 - CaO binary phase diagram and interface reaction characteristics that the temperature of $12CaO{\cdot}7Al_2O_3$ is higher during the slag interfacial melting process. Moreover, there are a lot of CaO materials at the interface, which leads to excessive viscosity and the poor fluidity of Al_2O_3 - CaO slag. It can be seen from Figure 2 that the formation of a higher temperature $12CaO{\cdot}7Al_2O_3$ at the interface, which makes it difficult to react. There is only a certain amount of interpenetrations between Al_2O_3 and CaO. However, the infiltration is not sufficient and there is no

Table 3 **Wetting angle of different binary systems**

Slag sample	CaO - MgO	Al_2O_3 - CaO	Al_2O_3 - MgO	SiO_2 - CaO	SiO_2 - MgO
Wetting angle / °	27	41	31	36	45

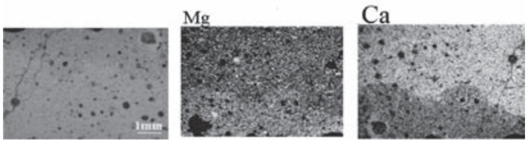

Figure 1 The electron microscope surface scanning at the interfacial reaction between CaO - MgO slag

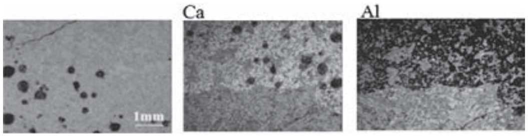

Figure 2 The electron microscope surface scanning at the interfacial reaction between Al_2O_3 - CaO slag

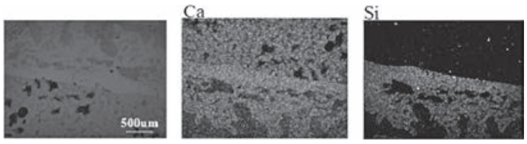

Figure 3 The electron microscope surface scanning at the interfacial reaction between SiO_2 - CaO slag

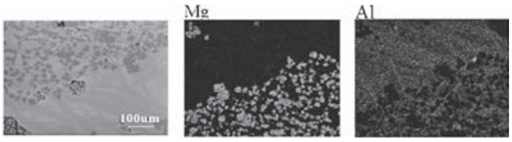

Figure 4 The electron microscope surface scanning at the interfacial reaction between Al_2O_3 - MgO slag

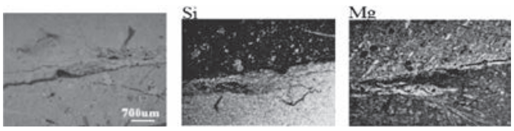

Figure 5 The electron microscope Surface scanning at the interfacial reaction between SiO_2 - MgO slag

obvious reaction interface layer. There is no obvious chemical reaction behavior between Al_2O_3 and CaO slag, so the composition and interface separation among each component are more evident.

Figure 3 shows the electron microscope surface scanning at the interfacial reaction between SiO_2 - CaO slag. When the interface reaction between SiO_2 slag and the CaO matrix occurs, the SiO_2 slag is prone to dissolve. It will react with CaO substrate to generate $CaSiO_3$ and $2CaOSiO_3$ at low melting point. The initial generation temperature of $CaSiO_3$ and $2CaOSiO_3$ is low, which further promotes the initiation of the reaction behavior and the process of wetting. It can be seen from Figure 3, there is an obvious infiltration of CaO material from the reactive matrix to slag. A clear reaction interface layer is appeared and the reaction is sufficient. Compared with other slag systems, the permeation and reaction at the interface of SiO_2 - CaO are relatively sufficient. The structure and composition of $CaSiO_3$ and $2CaOSiO_3$ are uniform and dense.

From the phase diagram of the Al_2O_3 - MgO binary slag, there is generated new phase $MgO{\cdot}Al_2O_3$, Al_2MgO_4 with higher generating temperature during the process of melting. It can be seen from Figure 4, there is only a certain amount of interpenetrations between Al_2O_3 and MgO. However, the permeation is not sufficient. It is most concentrated in the three-phase reaction interface of Al_2O_3, MgO and reaction products. It is found that compared with MgO matrix, Al_2O_3 slag permeates more completely. There is no obvious chemical reaction behavior at the interface. The composition and interface separation among each component are more distinctly.

From the phase diagram of the SiO_2 - MgO binary slag, it can be obtained that when SiO_2 and MgO start to react. $MgSiO_3$ and Mg_2SiO_4 with higher temperatures form at the reaction interface. SiO_2 - MgO slag wetting angle is the biggest, which is unfavorable to the reaction of the interface. It can be seen from the Figure 5, there is only a certain amount of chemical reaction behaviors between SiO_2 and MgO at the interface. At the reaction interface the penetration of SiO_2 is not obvious and MgO has a certain amount of diffusion from the reactive matrix to the slag. It is found from Figure 5 that the composition and the reaction interface are clear.

CONCLUSIONS

(1) There are different between variant reaction substrates and reactants, so the viscosity, the reaction process, the wetting process and the reaction behavior of different binary slag are also different. Due to the component of a binary system is relatively single that the reaction temperature and reaction interval depend mainly on its own single melting and reaction.

(2) During interfacial melting and reaction of different binary slag: the permeation and reaction at the interface of CaO - MgO and CaO - SiO_2 are relatively sufficient. The newly formed structure and composition of $CaSiO_3$ and $2CaOSiO_3$ are uniform and dense. As for CaO - Al_2O_3 and Al_2O_3 - MgO slag system, there is only a certain amount of interpenetrations between the two phases. After melting there is no obvious chemical reaction behavior at the interface and the composition and interface separation among each component are more obvious.

(3) In general, the wetting angle of acidic slag is higher than that the corresponding basic slag. The variation of wetting angle between different binary slag is relatively small, the variation range was only 18 °.

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